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The value of bitewing radiographs in epidemiological caries research: a systematic review of the literature

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Radiographs; Diagnosis;
Dental caries

Summary Objective. To assess whether radiographic examinations are necessary to evaluate (trends in) the prevalence of caries, a summary was made of data from epidemiological studies comparing the results of clinical and radiographic examinations in young populations.

Method. A literature search yielded seven studies that met the inclusion criteria. A two-by-two table of radiographic versus clinical data was constructed for each study. These data were used to assess the radiographic and clinical prevalences and to find a conversion factor to calculate the total prevalence from the clinical prevalence.

Results. In the approximal surfaces the radiographic prevalence was considerably higher than the clinical prevalence. The conversion factors to calculate the total prevalence from the clinical prevalence varied considerably across studies. In the occlusal surfaces the radiographic and clinical prevalences were about similar, but extra lesions were detected with both methods.

Conclusion. To study trends in the prevalence of caries, radiographic examinations are not necessary but to assess the prevalence of caries they do have unknown additional value. To obtain a valid conversion factor for relevant patient categories, agreement between the results of radiographic and clinical examinations should be investigated in sub samples of epidemiological studies.

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Introduction

In clinical caries care, radiographs (bitewings) form an indispensable addition to the visual inspection of the teeth. In epidemiological studies that are carried out to assess (trends in) the prevalence of caries, the additional value of radiographic

evaluation is under discussion. In the Netherlands, epidemiological studies focusing on the oral health of the young population (5-23 years) take place regularly.¹ The goal is to monitor trends in the prevalence of caries and oral health care in general. The prevalence of caries in these studies was usually based on clinical examination of the teeth, but recently radiography has also been used.¹ As this made it difficult to compare the results with those of previous evaluations, the question rose as to whether or not radiographic evaluation is

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necessary in epidemiological studies. A review was, therefore, performed to address the following research questions:

- What is the additional value of radiographic examinations (bitewings) compared to clinical examinations in studies to assess (trends in) the prevalence of caries in a young population?
- How many and what type of caries lesions were found on bitewings and not by clinical examination?
- How many and what type of caries lesions were found by clinical examination and not on bitewings?

Previous reviews on the additional value of bitewings did not focus on epidemiological studies.^{2,3} Dove² examined the sensitivity and specificity of radiographs in extracted teeth, using histological validation, or visual or tactile validation for intact surfaces. He concluded that the evidence was too poor to draw conclusions about the additional value. Clinical examination was not included in this review. Bader et al.³ compared both clinical examination and bitewings with histology as a gold standard for caries. There appeared to be large differences in sensitivity and specificity values between studies. They concluded that both clinical and radiographic examinations were unsatisfactory in detecting caries lesions.

This review focuses purely on epidemiological studies, in which case histology is not applicable as a gold standard. Radiographic examination cannot be considered as a gold standard for clinical examination either, because not every cavitation observed on the radiographs is accompanied by an interruption in the enamel and, moreover, some caries lesions are deeper than observed on the bitewing radiograph. Therefore, the diagnostic value is not expressed in terms of sensitivity and specificity. The results of clinical examination and bitewings are compared and an assessment is made of how many and what type of caries lesions are detected with one method and not with the other.

Clinical prevalence has been defined as the prevalence of caries observed only by clinical examination, radiographic prevalence as caries observed on bitewings, and total prevalence as clinical prevalence plus the extra lesions detected through radiography.

Methods

A search was made in Medline, using the search terms visual inspection, clinical examination,

radiograph, X-ray, bitewings, dental caries and alternative terms (see Appendix A), combined with the MESH terms sensitivity and specificity, which are terms used to identify papers on diagnosis.⁴ The reference lists of relevant papers were checked for additional studies. Experts in caries research in the Netherlands were also asked whether, in their opinion, any relevant studies had been missed.

Only papers written in English or Dutch, published after 1990, were selected. This time criterion was chosen because before 1990, the prevalence of caries was substantially higher. When the prevalence is higher not only the number of lesions is higher, but also the type of lesions may differ, and, therefore, also influence the results on diagnostic performance. Further inclusion criteria were: a young study population (<24 years), the study should include bitewings and a clinical examination, and it should be possible to construct a 2 × 2 table depicting the number of caries lesions detected by clinical examination only, radiographic examination only and by both methods, in relation to the number of surfaces examined. Studies that examined extracted teeth were excluded, as were studies in which the examined surfaces were selected on the basis of the presence or absence of caries detected with one of both methods.

The methodological quality of the papers that met the inclusion criteria was assessed according to criteria adapted from Devillé and Buntinx⁴ and the Cochrane Methods Group on Diagnostic and Screening tests (<http://www.cochrane.org/cochrane/srdt.htm>) (see Appendix B). These are generally accepted methodological criteria to assess the internal and external validity of diagnostic studies. Items related to the reference standard were adapted or omitted, because no reference standard was defined in this review.

For caries lesions found by only one of the two methods, the absolute numbers as well as the percentages per examined surfaces are presented. The results are presented for approximal and occlusal surfaces separately, and for different diagnostic thresholds, distinguishing caries lesions restricted to the enamel from caries lesions present in the dentine. Furthermore, suspect dentine, cavitation or white spot have been used as diagnostic thresholds. In the calculation of the prevalences, surfaces with filled cavities are considered to be 'sound' (no clinical or radiographic evidence of caries).

An attempt was made to find a conversion factor to predict the total prevalence from the clinical prevalence, by estimating the relative contribution of the radiographic prevalences. Therefore, a factor

was calculated, by which the clinical prevalence has to be multiplied to find the total prevalence in each study.⁵

Results

Of the 2412 studies identified in Medline with the relevant search terms, 2368 were excluded after the abstract was read. Of the remaining 44 papers, 37^{E1-E37} were excluded: one because the study population was aged > 25 years, 17 studies because no 2 × 2 tables could be constructed, and 14 studies because they were based on extracted teeth or separated teeth (see reference list of excluded studies). A study carried out by Weerheijm et al.^{E35} was excluded because it was based on data collected in 1967. Hintze and Wenzel,^{E11} Nyvad et al.^{E23} and Poorterman et al.^{E25,E26} were also excluded because they based their studies on data that were also reported in Hintze,⁶ Machiulskiene et al.,⁷ and Weerheijm et al.,⁸ respectively, which were already included in this review.

Methodological quality

Seven studies⁶⁻¹² met all the inclusion criteria. Their methodological characteristics are presented

in Table 1. All studies gave a description of the interpretation of the radiographic and clinical examinations. There were large differences in sample sizes (ranging from 123 to 962) and variable descriptions of non-participants and missing data. Some studies did not report on whether the two examinations were performed independently from each other.^{8,10,12} The methodological quality of all studies was satisfactory.

Table 2 presents an overview of missing values in the included studies. To evaluate the applicability of bitewings it is important to know how often no (useful) information was obtained. Five out of seven studies reported how many persons did not participate in the radiographic or clinical examinations. The percentage of non-participants varied from 2 to 34%. The percentage of surfaces that could not be properly assessed ranged from 0.7 to 36.8% and was higher for the radiographic examination than for the clinical examination. However, it has to be noted that surfaces that cannot be assessed by clinical examination are usually considered to be sound. Overlapping surfaces and radiograph errors are the most important reasons why surfaces cannot be radiographically assessed. Table 2 shows that no adequate data could be obtained by bitewings in approximately 20% of the population.

Table 1 Criteria for internal and external validity.

	de Vries ¹¹	Kidd ¹⁰	Weerheijm ⁸	Hintze ⁶	Machiulskiene ⁷	Poorterman ¹²	Fracaro ⁹
Same tests performed in all persons	Yes	Yes	Yes ^a	Yes	Yes	Yes	Yes ^b
Independent test-interpretation	Yes	? ^c	? ^d	Yes	Yes	? ^e	Yes
Description caries lesions radiographically	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Description caries lesions clinically	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Description non-participants	No	No	Yes ^f	Yes	Yes	Yes	Yes
Description missing data	Yes ^g	Yes	Yes	Yes	Yes	Yes	Yes
Number of persons	317	962	131,123,123	168	872	621	481
Age	14.3	15	14, 17, 20	14.0	11.7	17 and 20	8.1
Male/female	142/175	-	-	93/75	-	-	265/216
Description reproducibility	No	Yes ^h	Yes ⁱ	No	Yes ^j	Yes ^k	Yes ^l

^a The group of 17-year-olds were seen again three years later, then aged 20. Only those who were seen on both occasions are included in the study (not known how many were excluded for this reason).

^b Teeth showing caries or restorations in other surfaces are excluded.

^c Not reported explicitly, it is stated that different people interpreted the examinations, but not whether the results of the other examinations were known.

^d It is stated that the people who performed the clinical examinations assessed part of the bitewings, but it is not known whether the assessment of the bitewings was independent of all clinical data.

^e It is not stated whether the assessment of all bitewings was independent of all clinical data.

^f Number of excluded persons not known.

^g When bitewings were not readable because of overlapping surfaces (number not known), data were replaced by clinical findings.

^h Reproducibility is presented for radiographic examination; for clinical examination it is reported that the researchers had 25 years of experience.

ⁱ Reproducibility of clinical examination not presented.

^j Intra-examiner reproducibility is presented.

^k Reproducibility of clinical examination is not presented.

^l Reproducibility of clinical examination is based on 10 extracted teeth, radiographic reproducibility is based on 10 bitewings.

Table 2 Non-participants and missing data.

Studies	Non-participants N (%)	Reasons	Non-assessable surfaces N (%)	Reasons
de Vries ¹¹	-	-	92 bitewings (15%) with one or more unreadable surfaces	Overlapping surfaces
Kidd ¹⁰	154 (14)	Radiographical examination but no clinical data	246 (6.4%) first molars 1338 (36.8%) second molars	Missing teeth or non-readable bitewings
Weerheijm ⁸	-	-	14 years: 119 (11.4%): 74 bitewings, 10 clinical and 35 no data on both tests 17 years: 55 (5.6%): 24 bitewings, 19 clinical, 12 no data on both tests 20 years: 33 (3.4%): 13 bitewings, 10 clinical, 10 no data on both tests	Orthodontic apparatus + not full-grown teeth + missing teeth
Hintze ⁶	7 (4)	Not available for clinical examination or no bitewings made	Occlusal: 263 (10.0%) approximal: 1005 (17.0%)	Orthodontic apparatus + overlapping surfaces + radiograph errors
Machiulskiene ⁷	20 (2.2)	No permission from parents to participate	Non-readable bitewings occlusal: 598 (5.5%) approximal: 1843 (8.6%) Missing surfaces occlusal: 3127 (22.4%) approximal: 6418 (23.0%)	Orthodontic apparatus + overlapping surfaces + radiograph errors + missing teeth
Poorterman ¹²	330 (34.7)	(Possible) pregnancy, short time since previous bitewings, unwilling to participate, lack of time	110 (0.7%)	Bitewings not readable because of overlapping surfaces, + orthodontic apparatus + movement of film
Fracaro ⁹	165 (26)	No permission from parents to participate	219 teeth (10%)	No clinical/radiographic assessment possible

Prevalences

For the seven studies included in this review the radiographic prevalences, the clinical prevalences and the total prevalences were calculated. The data from the study carried out by de Vries¹¹ are used to illustrate how these prevalence rates are calculated for different diagnostic thresholds (Table 3).

Table 3 shows that on 19 surfaces caries lesions were found in the dentine by both radiographic and clinical examination. If we consider caries in the dentine (dentine as diagnostic threshold), $104 + 12 = 116$ extra lesions were found by radiographic examination, 104 of which are considered sound clinically and 12 are considered as caries in the enamel layer by clinical examination. These 116 lesions form 1.7% ($116/6781 \times 100$) of all surfaces examined. The radiographic prevalence of dentine caries is 0.02 ($135/6781$), and the clinical prevalence of dentine caries is 0.003 ($21/6781$). If

enamel is taken as diagnostic threshold ('caries in enamel or dentine' versus 'sound') $104 + 817 = 921$ extra lesions were found by radiographic examination, which is 13.6% ($921/6781 \times 100$) of all surfaces. The radiographic prevalence, therefore, amounts to $(135 + 965)/6781 = 0.16$, and the clinical prevalence is $(21 + 188)/6781 = 0.03$. Similarly, the extra caries lesions found by clinical examination can also be calculated. At the dentine level, $1 + 1 = 2$ extra lesions were observed by clinical

Table 3 Data from de Vries study¹¹ as an example of prevalence calculations.

de Vries ¹¹		Radiographic			
Clinical		Dentine	Enamel	Sound	
	Dentine	19	1	1	21
	Enamel	12	147	29	188
	Sound	104	817	5651	6572
		135	965	5681	6781

Table 4A Radiographic and clinical prevalences on *approximal* surfaces, extra caries lesions observed and conversion factor with dentine as diagnostic threshold.

Study	Diagnostic radiographic threshold	Diagnostic clinical threshold	P(r)	Extra lesions radiographic, % of total surfaces	P(c)	Extra Lesions clinical, % of total surfaces	P(t)	Conversion factor
de Vries ¹¹	Dentine	Dentine	0.017	116 1.7% of 6781	0.003	2 0.03% of 6781	0.02	6.7
Hintze ⁶	Dentine	Cavitation	0.02	99 2.0% of 4912	0.001	3 0.06% of 4912	0.02	21.0
Machiulskiene ⁷	Dentine	Cavitation	0.05	588 3.0% of 19643	0.02	82 0.4% of 19643	0.05	2.5
Poorterman ¹²	Dentine	Discontinuity of enamel	0.11	1224 10% of 12233	0.01	55 0.4% of 12233	0.11	11.0

Table 4B Radiographic and clinical prevalences on *approximal* surfaces, extra caries lesions observed and conversion factor with enamel/suspect as diagnostic threshold.

Study	Diagnostic radiographic threshold	Diagnostic clinical threshold	P(r)	Extra lesions radiographic, % of total surfaces	P(c)	Extra lesions clinical, % of total surfaces	P(t)	Conversion factor
de Vries ¹¹	Enamel	Enamel	0.16	921 13.6% of 6781	0.03	30 0.4% of 6781	0.17	5.5
Hintze ⁶	Enamel	Cavitation	0.09	440 9.0% of 4912	0.001	3 0.1% of 4912	0.09	91.0
Machiulskiene ⁷	Enamel	(In)active surface intact	0.10	1053 5.4% of 19643	0.13	1707 8.7% of 19643	0.18	1.4
Hintze ⁶	Enamel	Suspect cavitation	0.09	390 7.9% of 4912	0.04	155 3.2% of 4912	0.12	3.0

P(r), radiographic prevalence of caries; P(c), clinical prevalence of caries; P(t), total prevalence of caries.

examination, which is 0.03% ($2/6781 \times 100$) of all surfaces examined. This example shows the influence of the diagnostic threshold on the prevalence; the radiographic prevalence of 0.02 increases to 0.16 if caries in the enamel layer is also taken into account.

The prevalences of caries on the approximal surfaces are presented in [Tables 4A and B](#), and on the occlusal surfaces in [Tables 5A and B](#).

[Tables 4A and B](#) show that on the approximal surfaces the radiographic prevalences were found to be higher than the clinical prevalences in most studies, except in the Machiulskiene et al. study⁷ in which enamel lesions were used as diagnostic threshold. The differences between the radiographic and clinical prevalences vary from a few caries lesions per 100 surfaces examined^{6,7} with

'suspected' as diagnostic threshold, to 10 per 100 surfaces.¹²

[Table 5A](#) shows that on the occlusal surfaces, with dentine as the diagnostic threshold, the radiographic and clinical prevalences are approximately the same. However, in the study carried out by Weerheijm et al.⁸ the radiographic prevalence was much higher than the clinical prevalence. As [Table 5B](#) shows, with the enamel level or suspected caries lesions as diagnostic threshold, the clinical prevalences were higher than the radiographic prevalences, again with exception of the Weerheijm study. When the prevalences in the Weerheijm study are compared with those in other studies, the clinical prevalences are approximately the same (irrespective of the diagnostic threshold), but the radiographic prevalences in the Weerheijm study are substantially higher.

Table 5A Radiographic and clinical prevalences on *occlusal* surfaces, extra caries lesions observed and conversion factor with dentine as diagnostic threshold.

Study	Diagnostic radiographic threshold	Diagnostic clinical threshold	P(r)	Extra lesions radiographic, % of total surfaces	P(c)	Extra lesions clinical, % of total surfaces	P(t)	Conversion factor
Kidd ¹⁰	Dentine	Dentine	0.12	331 5.4% of 6074	0.11	251 4.1% of 6074	0.17	1.5
Weerheijm ⁸ age 14 years	Dentine	Dentine	0.29	216 23.3% of 929	0.10	43 4.6% of 929	0.33	3.3
age 17 years	Dentine	Dentine	0.28	222 23.8% of 934	0.06	25 2.7% of 934	0.30	5.0
age 20 years	Dentine	Dentine	0.30	239 25.2% of 948	0.06	12 1.3% of 948	0.31	5.2
Hintze ⁶	Dentine	Cavitation	0.02	38 1.6% of 2362	0.03	55 2.3% of 2362	0.05	1.5
Machiulskiene ⁷	Dentine	Cavitation	0.16	822 8.0% of 10227	0.13	493 4.8% of 10227	0.21	1.6
Fracaro ⁹	Dentine	Dentine	0.06	72 3.7% of 1929	0.05	40 2.1% of 1929	0.09	1.7

Table 5B Radiographic and clinical prevalences on *occlusal* surfaces, extra caries lesions observed and conversion factor with enamel/suspect as diagnostic threshold.

Study	Diagnostic radiographic threshold	Diagnostic clinical threshold	P(r)	Extra lesions radiographic, % of total surfaces	P(c)	Extra lesions clinical, % of total surfaces	P(t)	Conversion factor
Weerheijm ⁸								
age 14 years	Dentine	Suspect dentine	0.29	186 20.0% of 929	0.17	75 8.1% of 929	0.37	2.2
age 17 years	Dentine	Suspect dentine	0.28	212 22.7% of 934	0.08	27 2.9% of 934	0.31	3.8
age 20 years	Dentine	Suspect dentine	0.30	206 21.7% of 948	0.10	18 1.9% of 948	0.32	3.2
Hintze ⁶	Enamel	Suspect cavitation	0.02	34 1.4% of 2362	0.05	112 4.7% of 2362	0.06	1.3
Machiulskiene ⁷	Enamel	(In)active surface intact	0.16	596 5.8% of 10227	0.30	2025 19.8% of 10227	0.36	1.2
Fracaro ⁹	Dentine	Enamel	0.06	66 3.4% of 1929	0.15	236 12.2% of 1929	0.18	1.2

P(r), radiographic prevalence of caries; P(c), clinical prevalence of caries; P(t), total prevalence of caries.

Extra caries lesions

The extra caries lesions that were observed are presented in [Tables 4A,B and 5A,B](#) as absolute numbers and as percentages of the total number of approximal or occlusal surfaces examined. In the approximal surfaces the extra lesions that were detected by radiographic examination vary from 1.7 to 10% of all approximal surfaces with dentine level as diagnostic threshold ([Table 4A](#)) and vary from 5.4 to 13.6% on the enamel level ([Table 4B](#)). By clinical examination, extra caries were found on 0.03 to 0.4% of all approximal surfaces on the dentine level ([Table 4A](#)) and 0.1–8.7% on the enamel level ([Table 4B](#)). In all studies, more extra lesions were detected by radiographic examination than by clinical examination, except in the Machiulskiene et al. study,⁷ which used enamel as diagnostic threshold.

On the occlusal surfaces the number of extra caries lesions detected radiographically varies from 1.6 to 25.2% of all surfaces examined on dentine level ([Table 5A](#)) and from 1.4 to 22.7% on enamel level ([Table 5B](#)). By clinical examination of the occlusal surfaces 1.3 to 4.8% on the dentine level ([Table 5A](#)) and 1.9 to 19.8% on the enamel level ([Table 5B](#)) extra lesions were observed. The numbers of extra lesions detected by radiographic examination and by clinical examination are approximately the same, except in the study carried out by Weerheijm et al.,⁸ which reported a higher number of extra lesions detected by radiography.

Conversion factors

In order to assess the total prevalence on the basis of the clinical prevalence, a conversion factor was calculated according to Mann et al.,⁵ which expresses the factor by which the clinical prevalence should be multiplied to obtain the total prevalence. The calculation of the conversion

factor is illustrated by again using the data from the de Vries study¹¹ presented in [Table 3](#) as an example. The clinical prevalence is 0.003 (21/6781). The prevalence of radiographically detected extra lesions is 116 (1.7% of 6781) = 0.017. In that case, the total prevalence is $0.003 + 0.017 = 0.02$. The conversion factor is calculated as $0.02/0.003 = 6.7$. This means that to obtain the total prevalence the clinical prevalence should be multiplied by 6.7. The conversion factors in the included studies vary from 2.5 to 21 for the approximal surfaces, with dentine level as diagnostic threshold, and from 1.4 to 91 on the enamel level. For the occlusal surfaces, the conversion factors vary from 1.5 to 5.2 on the dentine level, and from 1.2 to 3.8 on the enamel level. If the Weerheijm et al. study⁸ is excluded, the conversion factors for the occlusal surfaces range from 1.5 to 1.7 for the dentine level, and from 1.2 to 2.2 for the enamel level, and these would then seem to be uniform conversion factors.

Discussion

The studies included in this review show that there is variation in the radiographic and clinical prevalence of caries, depending on the type of surfaces examined. On the approximal surfaces the radiographic prevalences are substantially higher than the clinical prevalences, but on the occlusal surfaces the radiographic and clinical prevalences are approximately the same for the caries in the dentine, with the exception of the Weerheijm et al. study,⁸ in which the radiographic prevalences are higher than the clinical prevalences in the enamel layer. The clinical prevalences found in the Weerheijm et al. study⁸ correspond with the values of the clinical prevalences found in the other studies, but the radiographic prevalences are substantially higher. One explanation might be that

Weerheijm et al.,⁸ while trying to distinguish filled surfaces with and without caries, have defined more filled and sealed surfaces as caries than has occurred in other studies. However, when all filled and sealed surfaces are excluded in the Weerheijm et al. study,⁸ the radiographic prevalences are still higher. Note, however, that if the radiographic prevalence equals the clinical prevalence, the total prevalence, in which the radiographically detected extra lesions are added to the clinical prevalence, might be higher.

This variation in prevalences can be attributed to the real differences in the prevalence of caries in the studied populations, but may also be partly due to other causes. For example, the definition of caries, and the thoroughness of the examination can also influence the prevalence. This type of information is difficult to report in a publication. The influence of the diagnostic threshold and the type of surfaces on the variation in prevalences has been eliminated by presenting the information in separate [Tables 4A and B](#), [5A and B](#).

The studies included in this review only examined occlusal and approximal surfaces, on which the greatest differences between radiographic and clinical examination are expected to be found: occlusal surfaces are difficult to assess because of fillings and fissures, and approximal surfaces are difficult to examine visually. When assessing the prevalence of caries in a young population, all teeth except the wisdom teeth are examined. A complete set of teeth consists for 12.5% of occlusal surfaces and for 43.75% of approximal surfaces. This should be noted if data from this review are used in connection with the prevalence of caries in a complete set of teeth.

All publications that met the inclusion criteria reported the number of caries lesions per surface (not per person or per tooth). This has two drawbacks: firstly, the dependency of the data is not taken into account and, secondly, it is impossible to interpret the data in terms of the number of persons with caries (at least one lesion) in the population.

There is a substantial number of missing data in the radiographic examinations. In approximately 20% of the population, on average, the bitewings provided no useable data. One of the reasons for this was unwillingness to participate in the radiographic examination, and another reason was that not all bitewings could be properly assessed because of overlapping surfaces or the presence of orthodontic apparatus. Rimmer and Pitts¹³ studied the prevalence of caries on overlapping surfaces by temporary teeth separation. It appeared that the clinical prevalence of caries on these overlapping surfaces is lower than that on other approximal surfaces, using as diagnostic

threshold either dentine, enamel or suspect lesions.¹⁴ Further study is needed to investigate the selectiveness of non-participation; in other words, does the prevalence of caries in non-participants differ from that in participants.

Do these data provide an answer to the question of whether radiographic examination, in addition to clinical examination, is necessary in epidemiological studies on the prevalence of caries in a young population? It should be noted that the included studies focus on the most difficult surfaces of a set of teeth. Obviously the radiographic prevalence is higher than the clinical prevalence, especially on the approximal surfaces, because these surfaces are difficult to examine visually. On the occlusal surfaces the presence of caries is difficult to assess, because of the presence of fillings and fissures. In a total set of teeth, the difference between radiographic and clinical prevalences will be relatively smaller. If a consistent conversion factor could be found to calculate the total prevalence on the basis of the clinical prevalence, radiographic examination would not be necessary. However, a large variation in conversion factors was found in this review.

Mann et al.⁵ also found a large variation in conversion factors based on a review performed by Haugejorden¹⁵ and concluded that the conversion factor is influenced by many factors, such as water fluoridation, oral health care, sugar consumption, etc. They propose conversion factors stratified according to the prevalence of caries, a measure for oral health care, and water fluoridation.⁵ In our opinion, the type of surface studied (approximal or occlusal) and the age of the population could be added, in which case stratified conversion factors would probably reach greater uniformity.

To determine trends in the prevalence of caries radiographic examination provides no additional value over clinical examination. This would have been the case if the caries lesions that can only be detected radiographically show a different trend to that of the clinically detected lesions. No indications for this could be found in the literature. To determine a trend in the prevalence of caries it is of utmost importance that the method of examination is the same for each assessment. This applies to both radiographic and clinical examination. If one wishes to change the method of examination, one examination with both the old and the new method is necessary to keep track of the trends. Note: archives of radiographs make it possible to re-examine previous radiographs on the basis of the new criteria.

Clinical examination will yield an under-estimation of the prevalence of caries on the approximal

surfaces. It should be noted that the starting point in this review was that both clinically and radiographically detected lesions were real caries lesions, but the lack of a gold standard to determine the presence of caries makes it impossible to verify this view. The addition of radiographic examinations increase the prevalence, but because of many missing values, either due to non-participation or radiographs difficult to interpret, the validity of the bitewings is uncertain. The high variation in the conversion factor is an indication of invalid measurements.

Conclusion

It is concluded in this review that radiographic examination has no additional value for determining epidemiological trends in the prevalence of caries in a young population. Although the radiographic prevalences in the approximal surfaces were found to be higher than the clinical prevalences, there are no indications that the trends and the prevalence of radiographically detected extra caries lesions are different from the trends in clinical prevalence. For the assessment of the prevalence of caries in a population at a certain point in time, however, radiographic examinations do have additional value, but the extent of this additional value is still unknown, because some people are unwilling to participate in radiographic examinations, and radiographs are not always interpretable. Therefore, the validity of radiographic examination can be questioned. As the difference between radiographic and clinical prevalences varies per study, no uniform conversion factor is available.

For longitudinal studies on the prevalence of caries it is recommended that clear definitions of caries are formulated and that consensus is achieved with regard to the method of examination. In small samples within these studies the correlation between radiographic and clinical examinations can be studied to obtain valid data for the construction of a conversion factor for relevant categories of patients or specific dental surfaces in the future.

Appendix A. Search terms in Medline

bitewing AND visual inspection OR bitewing AND detection OR bitewing AND clinical assessment OR bitewing AND tactile inspection OR bitewing AND adolescents OR bitewing AND children OR bitewing

AND sensitivity OR bitewing AND specificity OR bitewing AND clinical examination OR X-ray AND caries not in vitro OR X-ray AND dental caries AND children OR X-ray AND sensitivity AND specificity AND caries OR X-ray AND adolescents

Appendix B. Criteria for methodological assessment

Criteria for internal validity

1. Are the same examinations used for all patients (verification-bias)?
2. Are radiographic and clinical examinations assessed independently from each other (blinding)?
3. Are presence and absence of caries and types of caries lesions clearly defined radiographically?
4. Are presence and absence of caries and types of caries lesions clearly defined clinically?
5. Are numbers of non-participants and eventual reasons presented for both examinations?
6. Is there a description of how the researchers dealt with data missing or data difficult to interpret?
7. Is the reproducibility of the examinations presented?

Characteristics to assess external validity

8. What was the size of the study population?
9. What was the (mean) age of the study population?
10. What was the gender distribution?

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Double publication (#), Extracted teeth (±), Separated teeth (&), Age >23(^), No 2 × 2 table is presented or could be constructed from data in the study (*).

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